

Observations in the vicinity of a central Texas cave inhabited by millions of Mexican free-tailed bats establish the presence of rabies in the bat population and suggest a hypothetical route of transmission to raccoons and other carnivores.

Wildlife Rabies in Texas

—A Preliminary Report—

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RABIES is prevalent among Texas wild carnivore populations. In recent years the disease has been shown to occur in epizootic proportions in the gray fox, *Urocyon cinereoargenteus*, and skunks, chiefly *Mephitis mephitis* and *Spilogale* spp. (1).

In 1953 the Texas State Department of Health Laboratory confirmed positive findings of rabies in 150 foxes and 49 skunks taken from 44 and 20 counties, respectively. In 1954 it found rabies in 100 foxes and 71 skunks, from 33 and 29 counties, respectively. Occasionally,

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the laboratory has received wolves, coyotes, raccoons, and bobcats which laboratory tests proved to be positive for rabies.

Since animals are seldom submitted for laboratory examination unless they have invaded premises, usually diurnally, and have attacked domestic animals or human beings, it would seem obvious that the actual level of rabies infection among wild carnivores is much higher than our data indicate.

The recovery of rabies virus from insectivorous bats in Florida by Venters and his associates (2) and again in several other States by other investigators led to consideration of the role of bats in the maintenance and spread of the disease in nature.

In Texas, interest has centered around the Mexican free-tailed bat, *Tadarida mexicana*, as a transmitter of rabies to men and domestic and wild animals because this species is the most abundant and widespread in the State and virologists in the State health department have repeatedly recovered the virus in its brain and salivary gland material. These bats are commonly observed in natural retreats and buildings, and in the central part of Texas they are especially prevalent in certain limestone caves during all but the coldest winter months.

The teeth of *T. mexicana*, although sharp, are short and delicate. Hence, the means whereby the rabies virus could be transmitted to a furred and thick-skinned carnivore, such as the fox, skunk, or raccoon, appear limited. Two natural methods of infection transmission appear feasible:

Live, infected bats which become moribund and fall to the floor of the bat retreat may be able to inflict bites around or inside the mouths of animals attempting to devour them.

The rabies virus from an infected bat, if eaten, may penetrate the mucous membrane of the oral cavity, throat, or esophagus through an abrasion already present or possibly through an abrasion caused by a sharp bone.

Review of the Literature

Pursuant to the question of whether carnivores feed on bats, Allen (3) in his excellent book entitled "Bats," states, "Bats have few enemies." However, a search of the literature reveals an impressive list of mammals, as well as birds and reptiles, which feed on bats.

Campbell (4) tells of killing a "chicken snake" which had swallowed 14 bats from a colony in an old barn.

Davis (5) reports the recovery of a bat, *Molossus nigricans*, in good condition, which had been eaten by a rat snake, *Elaphe laeta*. We observed a colubrid snake consuming a free-tailed bat at the entrance of Ney Cave, near Bandera, Tex., in May 1954, but we do not know how the snake caught the bat. On another occasion, we saw a snake of comparable size and appearance at the same place, but it escaped into a rocky crevice before it could be collected.

Beer (6), Constantine (7), and Bailey (8) have recorded that predatory birds, such as hawks and owls, feed on bats, and on the Mexican free-tailed bat especially.

Sperry (9) recovered fragments of two silver-haired bats (*Lasionycteris noctivagans*) from the stomach contents of a skunk killed in January 1930, in Pisgah National Forest, North Carolina. At the same time and place, he also found a red bat, *Lasiurus borealis*, in the stomach of an opossum.

Taylor (10) in 1954 found that in Texas the red bat is a regular, although negligible, item

of the diet of the ringtailed cat, *Bassariscus astutus*, during the summer months. This nocturnal animal is arboreal and would probably take a greater number of solitary bats from the trees in which the bats spend the day if the bats were not also nocturnal.

Goodpaster and Hoffmeister (11) captured three minks having the remains of *Myotis* bats in their stomach contents. They took the minks in Carter County, Ky., at Carter Cave, which is inhabited by bats only during the winter months. These authors stated that the bats were hanging near enough to the cave floor for the minks to have reached them by jumping.

Bat Rabies Investigations

As part of our overall bat rabies investigations in the Texas State Department of Health, we have made regular observations of one of the largest bat colonies in the United States, in Bracken Cave near San Antonio. Only about 1,000 feet long, from 40 to 100 feet wide, and from 30 to 75 feet high, the cave harbors a multimillion population of *T. mexicana* and an appreciable number of *Myotis velifer* except for certain of the winter months.

During December through January there were no bats at all in the cave. Presumably, the free-tailed bats migrate south, possibly into Mexico, during the winter season and thus come within the range of the vampire bat. Just how far southward *T. mexicana* travels has yet to be determined.

In an effort to learn more about the ecology of this species, 3 of us banded approximately 5,000 individuals during 5 trips to the study cave in September and October 1954. During March-May 1955, approximately 10,000 more bats, chiefly *T. mexicana*, have been banded in this and other central Texas bat caves.

We used insect nets with extension handles for raking the bats off the walls and ceilings of the cave and placed the captured bats in an apple box, the top and bottom of which we covered with screen wire, adding a sliding panel door to the top. When a box contained a few hundred bats, it was taken to the cave entrance for banding.

Using the banding method described by Trapido and Crowe (12), we placed zero-sized



Entrance to one of the bat caves in central Texas where the State health department is conducting rabies transmission and migration studies.

aluminum bird bands on the distal portion of the forearm and adjusted the bands to permit free sliding along the bone without pinching the wing membrane. The United States Fish and Wildlife Service supplied the bird bands.

We found that one person could fasten the bands, pinching them together, as rapidly as two others, wearing leather gloves, could remove the bats from the box and hold out the forearm for banding.

Working during the summer months in these caves is very unpleasant because the guano is more than a foot deep in spots, ammonia fumes are strong, ectoparasites are abundant, and the heat is intense.

Regular monthly collections of bats have been made from the study cave for laboratory examinations.

The table illustrates the frequency with which

the virus of rabies was isolated from brains and salivary glands of *T. mexicanus*. Our laboratory has processed 329 bats of this species from Bracken Cave, collected from May 1954 through April 1955 in 98 pools. Twelve of the pools contained the rabies virus.

The specimens used for the pools were bats which were taken with the aid of insect nets from the cave walls or in flight or they were found moribund on the floor of the cave.

Our studies demonstrated that there may have been a high level of rabies infection in the free-tailed bats during May 1954–April 1955. That the colony had an extremely high mortality rate was evidenced by the fact that the cave floor was covered with dermestid beetle larvae and adults which devoured fallen bats. The maintenance of such an enormous dermestid population would require an appreciable supply

Rabies isolations from *Tadarida mexicana* taken in Bracken Cave, in central Texas, in 1954 and 1955

| Date collected ¹ | Number of bats | Number of pools | Number of positive pools | Source of virus |
|-----------------------------|----------------|-----------------|--------------------------|----------------------------|
| 1954 | | | | |
| May 6..... | 35 | 3 | 2 | Brain and salivary glands. |
| June 29..... | 37 | 5 | 1 | Brain. |
| July 30..... | 35 | 7 | 4 | Brain and salivary glands. |
| Aug. 30..... | 44 | 8 | 2 | Do. |
| Sept. 21..... | 27 | 6 | 2 | Do. |
| Oct. 8..... | 45 | 8 | 0 | |
| Nov. 19..... | 46 | 21 | 0 | |
| 1955 | | | | |
| Feb. 23..... | 25 | 25 | 0 | |
| Mar. 14..... | 10 | 10 | 0 | |
| Apr. 27..... | 25 | 5 | 1 | Do. |
| Total..... | 329 | 98 | 12 | |

¹ During December 1954 and January 1955 there were no bats in the cave.

of dead bats. Skeletal remains of bats in the guano were abundant throughout the cave.

Our earliest observations during the spring of 1954 confirmed Constantine's report for the National Speleological Society (7) that the bat caves in central Texas attract large numbers of predatory mammals and birds. We found that raccoons, in particular, were far more abundant around the study cave than the food supply appeared to justify, unless they were feeding on bats. Large accumulations of raccoon feces were in evidence at the mouth of the cave throughout the summer, but raccoon tracks or droppings were not found within the cave. The droppings found at the entrance to the cave did not contain any bat skin or bones.

It was not until November 18, 1954, after most of the bats had departed from the cave, that we had definite evidence of raccoons eating bats in numbers. When we noticed that raccoon tracks were abundant throughout the cave, we searched for concentration of scats (feces). Several recently deposited accumulations of fecal material contained bat fur and bones; some of the scats contained nothing but the remains of 5 to 10 bats, but others also con-

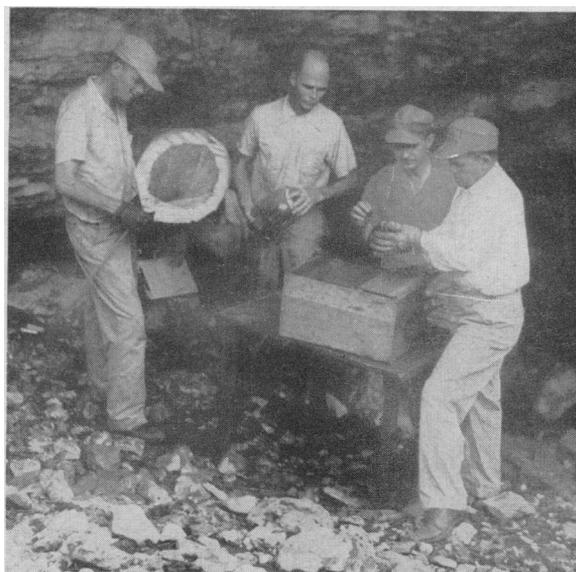
tained insect fragments and seeds of the black persimmon, a major item of the raccoon diet during the summer.

We were surprised to find in one of the scats an aluminum band still attached to a portion of bat fur and forearm. We identified the band as having come from a free-tailed bat banded in the study cave on September 29, 1954.

Migration had reduced the colony by November 1954 to a few thousand bats, hanging night and day from the highest ceiling area at the rear of the cave. With the advent of cold weather, the bats appeared to have discontinued their evening feeding flights, thus giving a raccoon or other carnivore little chance of reaching a bat unless it fell to the floor.

Early in December 1954 we baited 6 live traps with sardines and raw hamburger and set them in the study cave in order to collect raccoons for our bat-to-carnivore rabies transmission experiments. The first night of trapping produced 1 raccoon (*Procyon lotor*) and 2 damaged traps from which the raccoons had escaped. The second night we took 2 more raccoons from 4 traps within the cave. On the third night we baited 2 traps and took another raccoon. These animals freely fed on bats in the laboratory.

On April 28, 1955, large quantities of rac-



Banding Mexican free-tailed bats at a cave entrance.



Guano-encrusted rocks on the floor of a bat cave.

Right: Closeup of bats on the wall.



coon feces were again noted at the entrance of Bracken Cave. These were composed largely of bat skin and skeletal material.

A Hypothetical Explanation

The abundance of the raccoons and other carnivores in the vicinity of the large bat caves of central Texas strongly indicate that these animals occasionally feed on bats which fall near the cave entrances during the spring and late summer months.

Our observations show that in the autumn and spring, when other foods, and particularly the black persimmon, become less abundant or absent, raccoons enter the caves and actively search for fallen bats. For a limited period of time bats are an important dietary item of the raccoon in these restricted areas. Thus the possibility of the transmission of rabies from bats to these carnivores exists, but the exact mode of this potential interspecies transmission remains to be demonstrated.

Our investigations have established the isolation of the rabies virus from 12 out of 98 pools containing 329 bats during the period from May 6, 1954, to April 27, 1955, but the virus was not found in 64 pools containing 126 bats collected from October 1954 through March 1955. It seems probable that the presence of the disease might help to account for the number of bats that fall to the floor of the cave and serve as food for the raccoons.

This relationship provides a hypothetical explanation of the way in which rabies might pass from bats to raccoons. Evidence from the literature indicates the possibility of similar transfer to ringtailed cats, skunks, opossums, and other animals. However, the mechanism of transfer has not been found.

Summary

Investigators in the Texas State Department of Health report observations of a close association between Mexican free-tailed bats (*Tadarida mexicana*) and certain carnivores, especially the raccoon. During November 1954 and April 1955 they examined a number of raccoon droppings found within a central Texas cave inhabited by a colony of the free-tailed bats. The droppings were composed largely of bat fur and bone. The State health department laboratory has demonstrated a high level of rabies infection in the bat population within the study cave. Transmission of the rabies virus to raccoons and other carnivorous animals through the agency of infected bats is being investigated.

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Memorial to Dr. T. Duckett Jones

Support of young investigators and long-range medical research is promised by a fund recently established in honor of Dr. T. Duckett Jones, who died in 1954.

Jones was medical director of the Helen Hay Whitney Foundation, which is cooperating with the memorial committee. He advocated the creation of long-tenure positions for experienced investigators in universities and research institutions and aid to carefully selected, unrecognized researchers which might permit them to demonstrate their competency. His ideas and suggestions influenced research programs of a number of American institutions, including the National Institutes of Health and the American Heart Association.

The committee feels that research in rheumatic fever, the subject of much of Jones' own research activity, should be given first consideration in the assignment of its resources, but not an exclusive claim.

Mrs. James B. Campbell is chairman of the committee. Other members are Dr. E. Cowles Andrus, Dr. Walter Bauer, Dr. Francis L. Chamberlain, Mrs. Albert D. Lasker, Dr. H. M. Marvin, Dr. Jean Jones Perdue, Dr. David D. Rutstein, Dr. Leonard A. Scheele, Dr. Frederick K. Trask, and Dr. Paul D. White.